

130U-1

## SURVEYING

AG 130-U

### UNIT OBJECTIVE

After completion of this unit, students will be able to list the uses of surveying, perform land measurements, and determine the difference in elevation between two or more points. This knowledge will be demonstrated by completion of assignment sheets and a unit test with a minimum of 85 percent accuracy.

### SPECIFIC OBJECTIVES AND COMPETENCIES

After completion of this unit, the student should be able to:

1. List the uses of surveying.
2. Perform land measurements, including pacing and taping of linear distance.
3. Set up and level an instrument and read a rod, ruler, or tape.
4. Determine the difference in elevation between two or more points.
5. Be able to demonstrate proper use of a hand level or clinometer.

## SURVEYING IN AGRICULTURE

### A. Definition of Surveying

1. Surveying is the art of making relatively large precise measurements with a maximum of accuracy and with a minimum of time and labor.
2. Surveys result in the measurement of one or more of four types of dimensions. These are:
  - a. Horizontal Lengths
    - 1) An example is the measurement of the length of one side of a barn.
  - b. Vertical Lengths
    - 1) An example is the measurement of the height of a barn.
  - c. Horizontal Angles
    - 1) An example is laying out the line of a new fence that will be exactly at a right angle (90 degrees) to an existing fence.
  - d. Vertical Angles
    - 1) An example is the slope of a hillside.

### B. Purposes of Surveying

1. It provides field information needed for making maps, charts, and drawings that give exact positions and relative elevations of land, structures, and features.
2. It provides a means to lay out the position, determine the elevation, and check the final construction of land improvements.

### C. Uses of Surveying

1. Determine the area of a tract of land.
2. Determine an exact description of the boundaries of a tract of land in terms of engineering measurements of distance and angles.
3. Determine the exact or relative elevation of a series of points in a tract of land.

4. Locate exact land or structural boundaries.
5. Lay out exact land or structural boundaries.

#### D. Uses of Surveying in Agriculture

1. Determining the length of the boundary of a tract of land or the length of a side of a structure.
2. Determining the height of a tree, structure, or hill.
3. Determining the area of a plot of land in acres or the size of a building in square feet.
4. Determining legally specific land boundaries.
5. Determining slopes of land for design of irrigation systems.
6. Determining slopes of land for design of terracing systems.
7. Determining slopes of land for installation of a drain line or a ditch.
8. Determining exact or relative elevation of land to locate ditch pads or other agricultural structures.
9. Locating exact location and orientation of the boundaries of land or the sides of structures.
10. Laying out the exact angles of sides of structures or land boundaries.

### SURVEYING EQUIPMENT

#### A. Steel Tape

1. 100 foot long steel tape (sometimes called a "chain") is most commonly used to measure horizontal distances.
  - a. Has an accuracy of 0.05 feet when used properly
2. Metallic cloth tapes or cloth tapes are also used however, they are generally not as durable or as accurate as steel tapes.
3. Tapes are graduated (marked) in feet and 10ths and 100ths of a foot along their length.
4. Care of the Steel Tape
  - a. Prevent the formation of loops in the tape. If tension (pull) is applied to a looped tape, it can break or permanently kink.
  - b. Loops can be prevented by always keeping a bit of pull on the tape such that no slack develops.
  - c. For measurements of less than the full tape (100 feet), keep the tape on the reel.

- d. When using the full length of the tape off the reel, move it by dragging from one end only.
- e. When a tape is wet, clean and oil it as soon as possible.

## 5. Use of the Steel Tape

### a. Measuring the distance between two points (Point A to Point B)

- 1) Points A and B should be identified with a range pole or other such fixed marker (benchmark, corner of a building, etc.).
- 2) The head tapeman unreels the tape by walking toward point B while the rear tapeman holds the 100 foot end of the tape as near as possible over point A.
- 3) If the head tapeman reaches the end of the tape, the tape should be removed from the reel and a handle or thong attached to the end of the tape.
- 4) If the head tapeman reaches the end point of the tape before reaching point B, the head tapeman should stop and be "lined in."
- 5) The "lining in" process is directed by the rear tapeman to assure measurement along the line to be measured.
- 6) Using hand or verbal signals, the rear tapeman directs the head tapeman to near alignment with point B (which is still in the distance). At this time, the rear tapeman calls out "tape." The head tapeman then stoops, kneels to the left side of the tape and is more accurately "lined in" by the rear tapeman.
- 7) When the tape is on line, the rear tapeman kneels across the tape so that he can sight directly across it (at the "100 foot" reading) to point A.
- 8) The head tapeman should apply tension to the tape (usually 10 or 20 pounds of pull when using a spring gage). When the rear tapeman is centered over Point A (or a chain pin from a previous 100 foot measurement), he will call out "mark" or "right here" at which time the head tapeman will set a pin at the "0" mark of the tape.
- 9) When the head tapeman reaches point B before the end of the 100 foot tape, he stops and the rear tapeman comes up to the last pin that was set before Point B. The tapemen adjust the tape so that an even foot mark is opposite the rear tapeman's pin.

- 10) The tape is adjusted such that Point B is within the 0 to 1 foot section of the tape and an exact foot mark is held over the last pin before pin B. The head tapeman pulls tension on the tape and reads the tape to 10ths or 100ths as desired.
- 11) The number read by the head tapeman is subtracted from the foot reading being held by the rear tapeman. If the rear tapeman is aligning the 28 foot line over the last pin and the head tapeman reads 0.44 feet, then a subtraction gives the last distance as  $28.00 - 0.44 = 27.56$  feet.

#### B. Chaining Pins

1. These are steel wire pins about 12 inches long, sharpened on one end and looped at the other end.
2. They are used to mark off exact measurement points along a measured line.

#### C. Range Poles

1. They are normally about 8 foot long and painted alternately red and white for visibility.
2. Range poles are used to mark the two end points of a line to be measured.

#### D. Plumb Bob

1. This is a conical piece of metal hung from a string.
2. It is used to assist in measuring true horizontal distance on uneven terrain. This is done by hanging the plumb bob string over the tape (after the tape has been stretched to be level horizontally) and allowing the plumb bob tip to touch the ground to mark the point of measurement or reference.

#### E. Odometer

1. This is a wheel-like device (normally the diameter of a child's bicycle wheel) with a push handle and a revolution counter which is used to measure horizontal distance.
2. On smooth, horizontal surfaces, this device can measure horizontal distances to within 1%.

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- a. It is not normally recommended for use for accurate measurement on rough ground or across heavy vegetation.
3. The odometer measures distance by counting the number of revolutions of a wheel of known circumference.
  - a. The horizontal distance measured in feet is equal to 3.1417 times the number of revolutions of the wheel when traversing the line to be measured multiplied by the diameter of the wheel in feet.
4. Using the Odometer to Measure Distances
  - a. Set the odometer at the starting point of the line to be measured in such a way that the counter is just beyond the point where it makes the first count.
  - b. Set the odometer back to a zero count reading. If the counter cannot be zeroed, record the reading on the counter.
  - c. Begin to roll the odometer along the line to be measured at a normal walking pace.
  - d. Stop at the end of the line to be measured and record the counter reading.
  - e. If started from a counter reading of zero, the final reading will be the net count number and will be used to compute the measured distance. Otherwise, subtract the final reading from the initial counter reading and this number will be the net counter number to compute the measured distance. If the odometer has a conversion scale, use this to convert the net count number to the distance measured. Otherwise, multiply the net count number times 3.1417 times the diameter of the odometer wheel in feet to obtain the distance measured in feet.

## F. Tripod Level

1. This is a high-powered telescopic sight with a sensitive spirit level attached to it; it is adjusted so that when the bubble is centered, the line of sight is level.
2. Uses of a Tripod Level
  - a. Differential leveling
  - b. Profile leveling

### 3. Components of a Tripod Level

- a. Telescope
- b. Three or four leveling screws
- c. Leveling plate and head for fastening the level firmly to the tripod
- d. Tripod

### 4. Setup of the Tripod Level

- a. Spread the legs of the tripod three to four feet apart and push them individually and firmly into the ground.
- b. Adjust the tripod such that the leveling head (head plate) is approximately level and the telescope is near eye height. Tighten the thumb nuts on the legs to provide rigidity.
- c. Mount the level to the headplate by screwing it down.
- d. Loosen the telescope clamp and swing the telescope barrel directly over two of the leveling screws.
- e. Adjust these leveling screws by tightening one and loosening another simultaneously in order to center the bubble in the bubble tube.
  - 1) This is best accomplished by moving the thumbs together to move the bubble one way and by moving the thumbs away from one another to move the bubble the other way. The bubble will follow the direction of movement of the left thumb.
- f. Turn the telescope over the other pair of leveling screws and repeat the process in order to level the bubble.
- g. Since the process of leveling over one set of leveling screws will affect the level over other screws, the process must be repeated several times over each combination of leveling screws. When level, the bubble will stay level or nearly level throughout a complete 360° rotation of the telescope.
- h. Look through the telescope and focus the cross hairs by adjusting the eye piece with a rotary sliding motion.
- i. Focus on the level rod by turning the objective focus knob.
- j. Check the bubble tube immediately before and after each rod reading. Make any necessary adjustment before the reading is considered correct.
- k. Stand in one position as much as possible when making readings. Stand between the legs of the tripod rather than straddling them; avoid kicking or bumping into the tripod legs.

## G. Leveling Rod

1. This is a wooden rod graduated upward from zero at the bottom. It is the tool used to measure distance from the reference plane (at the bottom of the level rod) to the line-of-sight through the level.
  - a. The rod is graduated to feet, 10ths of a foot, and 100ths of a foot.
  - b. The level rod may or may not have a target for use in making readings.
2. A self-reading rod is commonly used and does not have a target. The readings can be taken directly from the person looking through the level telescope.
3. Reading the Level Rod (See page 130U-33)
  - a. Whole feet are delineated by the longest pointed markings on the rod that point at large red numbers.
  - b. The 10ths and 100ths are indicated by smaller divisions between the foot markings.
  - c. Each 10th of a foot division is delineated by a shorter pointed marking as well as by a black number. The exact reading is read at the flat edge of the sharp point.
  - d. Each 100th of a foot division is delineated by alternating black and white markings between the 10th markings. The 100th values are read at the edge of the black or white line, i.e., each marking is 1/100th of a foot wide.
4. Using the Level Rod with the Level
  - a. The person handling the level rod is known as the rodman, whereas the person using the level is the instrument man.
  - b. The rodman must hold the rod in an exact vertical position or the rod will give an incorrect distance from line-of-sight to the point being measured.
  - c. The rod should be held lightly, with the fingers on the edge of the rod. Holding the elbows firmly against the ribs will help to stabilize the rod.



## H. Hand Level or Clinometer

1. This is a hand-held device used to make less accurate surveying measurements and estimates.
2. Its components are:
  - a. A sighting tube with a horizontal cross hair to mark the line-of-sight
  - b. A bubble tube
  - c. A small mirror to show a reflection of the bubble through the eyepiece
  - d. Note: When the reflection of the bubble is centered on the horizontal cross hair, the line of sight is horizontal.
3. Uses of a Hand Level or Clinometer
  - a. Used with a level rod to measure slopes
  - b. Used with a board that is marked for locating contour lines
4. Use of a Hand Level with a Level Rod to Measure Slopes
  - a. The level person stands halfway down the slope to be measured.
  - b. The rodman stands approximately 50 feet upslope from the level person with the level rod in the appropriate position.
  - c. The level person sights through the hand level, achieves a horizontal line-of-sight on the level rod and records the reading on the level rod (see procedures in paragraph G-3 above).
  - d. With the level person remaining in the same location, the rodman moves exactly 100 feet down the slope and sets the level rod.
  - e. The level person turns around and repeats step c. above.
  - f. The slope (in percent) is equal to the numerical difference in the two readings. For example:
    - 1) The upslope reading on the level rod is 3.7 feet.
    - 2) The downslope reading on the level rod is 9.9 feet.
    - 3) The distance between the measured points is 100 feet.
    - 4) The slope is  $9.9 - 3.7 = 6.2\%$ .
5. Use of the Hand Level to Locate Contour Lines
  - a. A contour line is a line of equal elevation (height) on the earth's surface. More commonly, a contour line is thought of as a line of equal elevation around a hillside. Cattle trails that appear to

go horizontally around a hill can be thought of as crude representations of contour lines.

- b. Locating contour lines can be useful in laying out terraces, guides for tillage operations in contour farming, or laying out the centerline for a roadway around a hillside.
- c. Procedure:

- 1) Initially, the level person determines his or her eye height by sighting on a mark on the level rod, a mark on a board, or a feature or mark on the rodman.
- 2) The initial point on the contour line is selected and the level person stands at this location.
- 3) The rodman moves 50 to 100 feet along the approximate contour line.
- 4) The rodman is directed up or down the slope by the level person sighting through the hand level at the chosen mark (on the level rod, board, or rodman).
- 5) When the cross hairs are aligned with the mark and the bubble, the level person is on the contour line and should drive a stake at this location.
- 6) The rodman should remain by the stake just driven and the level person should move ahead on the approximate contour line to approximately 50 to 100 feet beyond the rodman.
- 7) The level person then sights back to the rodman and moves himself up or down the slope until the cross hairs again line up with the chosen mark on the rodman. At this point, the level person is on the contour line and should drive in a stake.
- 8) The rodman then leapfrogs past the level person as before and the procedure is repeated until the entire contour line has been located.

## LAND AREA MEASUREMENTS

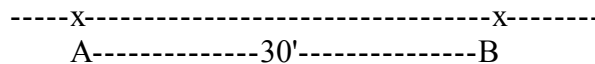
### A. Pace

1. A pace is the distance (in feet) from the heel of one foot to the point where the heel of the other foot hits the ground.
2. Distances can be measured by pacing when no greater than 2% accuracy (2 feet in 100 feet) is required.

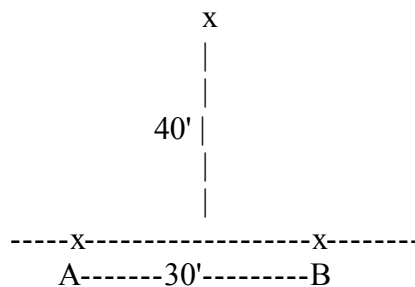
3. Pace can be determined by the following technique:
  - a. Accurately measure off a 100-foot distance.
  - b. At a normal walk, count the number of steps it takes to cover the 100 feet.
    - 1) It is best to walk the 100 foot course three times and take average number of paces required to complete the course.
  - c. To determine an individual's pace, divide the average number of steps into 100. For example, if it takes an average of 35 steps to cover the 100 foot distance, individual's pace is  $100/35 = 2.9$  feet.
4. When using pace to determine distances, it is best to determine pace under the same conditions that the distance is to be measured.
  - a. For example, pace will vary if measurements are taken uphill or downhill, in wet or muddy conditions, in tall or short vegetation, or in loose or firm soil.

### B. Laying Out a Right Angle (90° angle) with a Tape (3-4-5 method)

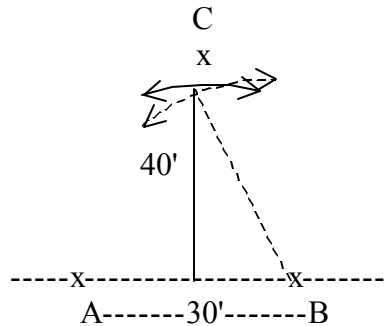
1. Lay out either a 3' or 30' measurement along the base line as depicted below.



2. Measure a line (4' or 40') from one end of the first line (Point A below) and scribe an arc such that line AC is approximately perpendicular (at right angles) to the line AB.



3. Measure a line (5' or 50') from the other end of the base line (Point B) to where it intersects with the scribed arc from step 2 above. When the distance BC is 50', then a right angle has been formed.
4. Set a pin or stake where the two arcs intersect (Point C).



C. Using the tape to determine field area (in square feet and acres).

1. Measure the sides of the field (in feet) using one of the techniques described previously.
2. Calculate the area of the field in square feet.
3. Divide the area of the field in square feet by 43,560 square feet to determine the area of the field in acres.
  - a. There are 43,560 square feet in one acre. For example: if a field is measured and determined to have 85,000 square feet, the number of acres in the field can be determined by the following computation:

Area in acres =  $85,000/43,560 = 1.95$  acres.

4. Use the following formulas to determine the area of common geometric-shaped fields:
- a. Square or rectangular fields:

1) Area = (width)(length)

Where,  
width = width of the field in feet  
length = length of the field in feet

## b. Triangular fields:

$$1) \text{ Area} = (1/2)(b)(h)$$

Where,

b = length of the base of the triangular field in feet

h = perpendicular height to the base of the triangular field in feet

## c. Circular fields:

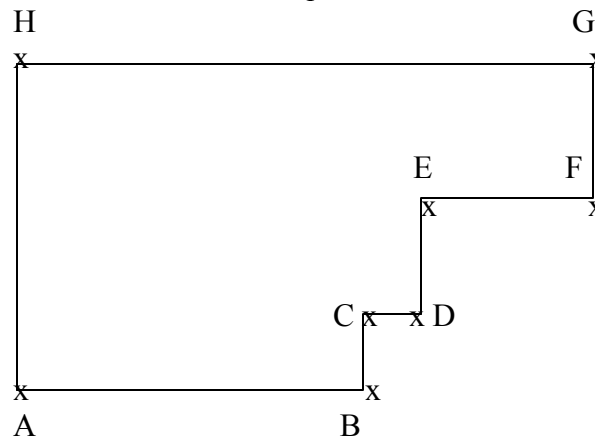
$$1) \text{ Area} = (3.1417) \rightarrow R^2$$

Where,

R = radius of the field in feet

## d. Irregularly-shaped fields:

- 1) Make an accurate (scale) drawing of the field.
- 2) Break the field down into recognizable shapes and compute the area of each part.
- 3) Add all of the areas of the parts of the field to get the total area of the whole field. For example: you have measured off the field pictured below. Compute the area of the field in square feet and in acres.

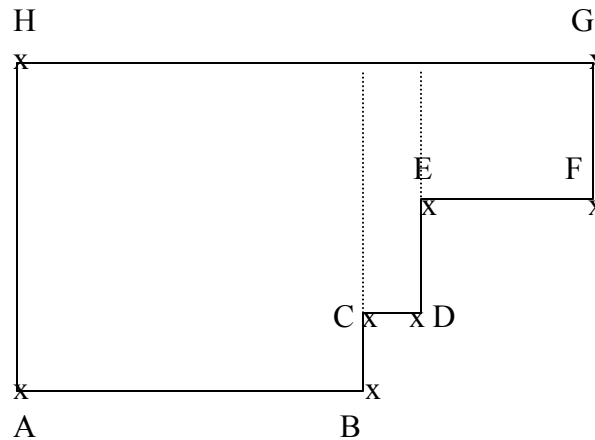


Given:

AB = 300'	EF = 200'
BC = 100'	FG = 250'
CD = 100'	GH = 600'
DE = 150'	HA = 500'

Solution:

Break the field down into recognizable shapes and compute the area of each part:



Compute:

1. Area of rectangular section defined by connecting points  
 $ABCC'HA = (AB)(HA) = (300)(500) = 150,000$  square feet.
2. Area of rectangular section defined by connecting points  
 $CDEE'C'C = (CD)(DE + FG) = (100)(400) = 40,000$  square feet.
3. Area of rectangular section defined by connecting points  
 $EFGE'E = (EF)(FG) = (200)(250) = 50,000$  square feet.
4. Add all of the parts to get the total area of the field:  
 $\text{Area} = 150,000 + 40,000 + 50,000 = 240,000$  square feet.
5. Convert the area in square feet to acres:  
 $\text{Area} = 240,000/43560 = 5.5$  acres.

#### D. Land Description

1. The rectangular system of land survey is used in 30 western states in the U.S.
2. This system is based upon the following subdivisions:
  - a. Quadrangles are square tracts of land approximately 24 miles on each side.
  - b. Quadrangles are subdivided into 16 townships, each approximately 6 miles on a side.
    - 1) Townships are bounded on the north and south by township lines and on the east and west by range lines.

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- c. Townships are subdivided into 36 sections, each approximately 1 mile on a side and containing 640 acres.

1) Sections are numbered by starting in the northeast corner and continuing west and east across the township as shown below: (also see page 130U-27)

-----					
6	5	4	3	2	1
-----					
7	8	9	10	11	12
-----					
18	17	16	15	14	13
-----					
19	20	21	22	23	24
-----					
30	29	28	27	26	25
-----					
31	32	33	34	35	36
-----					

- d. Sections are subdivided into quarter-sections, each approximately 1/2 mile on a side and containing 160 acres.
- e. Quarter-sections may be divided into fractional areas, the individual tracts containing 80, 40, 20, 10, or 5 acres or combinations of these.
- f. Section descriptions must include the section number, range number, township number, and principle meridian (In Idaho the principle meridian is the Boise Meridian, BM)

Activity:

1. Fill in the land description on worksheet #1.

## DIFFERENTIAL LEVELING

## A. Mapping the Topography of a Field

## 1. Purpose

- a. To determine the relative ground surface elevations of a tract of land and to plot those elevations on a base map.
- b. Completion of the above enables determination of cuts and fills to grade the land for an exact slope for surface irrigation.

## 2. Procedure

## a. Staking the Field

- 1) Stakes should be set at equal distances across the field to be surveyed.
- 2)  $3/8" \times 1-3/4" \times 4'$  lathes pointed at one end are commonly used.
- 3) A survey reading will be taken at each stake location in order to enable calculation of relative topography of the field.
- 4) A field set up with stakes might look like:

x-----x							
	0	0	0	0	0	0	
	0	0	0	0	0	0	
	0	0	0	x	0	0	
	0	0	0	0	0	0	
	0	0	0	0	0	0	
x-----x							

0 Stake location

x Level location

## b. Setting and Reading the Level (See page 130U-xx)

- 1) The level should be set at the center of the field as indicated above.



- 2) The level should be set up and leveled as described previously or as described in the operator's manual for the level.
- 3) A level rod reading is taken at each stake location.
  - a) If the ground is soft, a tractor can be driven along the line of stakes and rod readings can be taken in the wheel tracks.
- 4) Differences in rod readings for each stake represent differences in elevation at each stake.
  - a) The rod reading itself represents the vertical distance from the ground at each stake to the level of the cross hair in the level instrument.
  - b) The relative elevation at a particular stake location is higher when the rod reading is small.
  - c) The relative elevation at a particular stake location is lower when the rod reading is large.

c. Recording Information

- 1) A rod reading is recorded for each stake in the field.
- 2) Rod readings should be recorded for a permanent reference point location (called a bench mark or BM) as well as at each corner of the field.
  - a) A benchmark is a marked point of known elevation. They should be marks that are easily recognized, easily found, and not likely to be moved. They can be cross marks or bronze tablets set in masonry in a good foundation or they can be a certain part of a fire hydrant, pump base, or nail in a tree.

d. Producing a Base Map

- 1) If the exact elevation of the reference BM is not known, it is common to assume it is 100 feet in elevation.
- 2) Add the rod reading at the benchmark to the elevation of the BM.
  - a) The resulting number is the elevation of the cross hair in the instrument.

- 3) At subsequent stakes, subtract the stake rod level reading from the number computed in paragraph 2). above.
- 4) The following map illustrates recording of the pertinent rod reading information:

X-----X					
	0	0	0	0	
	3.20	3.42	3.46	3.22	
	0	0	0	0	
	3.21	3.44	3.46	3.21	
	0	0	x 0	0	
	3.21	3.44	3.46	3.22	
	0	0	0	0	
	3.21	3.44	3.48	3.21	
	0	0	0	0	
	3.20	3.45	3.47	3.22	
BM-----x					

3.00' = height of instrument (cross hairs)

0 Stake location

3.22' Rod reading at each stake in feet

x Level location

BM Bench mark location = 100 feet (assumed)

- 5) The following base map represents the surveyed field with the elevations relative to the 100 foot BM.

Elevation of the cross hair =  $100.00' + 3.00' = 103.00'$

$103.00 - 3.20 =$

x-----x					
	0	0	0	0	
	99.80'	99.58'	99.54'	99.78'	
	0	0	0	0	
	99.79'	99.56'	99.54'	99.79'	
	0	0	x 0	0	
	99.79'	99.56'	99.54'	99.78'	
	0	0	0	0	
	99.79'	99.56'	99.52'	99.79'	
	0	0	0	0	
	99.80'	99.55'	99.53'	99.78'	
BM-----x					

100.00'

6) Interpretations from the mapping:

- a) All stakes within the field are lower than the BM location.
- b) The field is low through the middle and high at the left and right sides.

B. Differential Leveling

1. Purpose

- a. Differential leveling is used to determine the difference in relative elevation of several points that are varying distances apart.
- b. It is commonly used to establish relative elevations of permanent points (called benchmarks) around the farm which are useful for making drainage and soil conservation surveys.
- c. Differential leveling is similar in form to mapping the topography of a field as described above. Typically involves resetting the level (i.e., moving it from location to location) and a more involved set of record keeping and calculations.

2. Procedure

- a. The procedures for differential leveling will be detailed with the aid of the example below. The surveying problem is to determine the elevation of points TP-1, TP-2, and TP-3 as diagrammed below. The BM elevation is known and is 100.00 feet. Because of obstructions and distances, it will be necessary to reset the level at four locations (designated by X's) below.

0 TP-1	X#2	0 TP-2
		X#3
X#1		
		0 TP-3
0 BM	X#4	

X#1 FIRST LEVEL SET-UP LOCATION

- b. Set up and level the instrument at the approximately halfway between the BM and TP-1.

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- 1) It is generally recommended that the distance from the instrument to the benchmark not exceed 400 feet; approximately 200 feet is the usually recommended distance.
  - 2) It is also recommended that the instrument be set up close to halfway between two benchmarks in order to cancel out leveling errors.
- c. Send the rodman to the BM and record the rod reading (3.02') at this point. This is what is known as a backsight (BS) reading and is recorded under BS in the field notebook.
- 1) A backsight (BS) reading is sometimes designated with a + sign and always results from a reading at a point of known or calculated elevation.
  - 2) Add the BS reading to the elevation of the BM to give the height of the instrument (HI), i.e.,  $HI = 3.02' + 100.00' = 103.02'$ .
- d. Move the rodman to station TP-1, take a rod reading (3.68') and record this as a foresight (FS) reading in your field notebook.
- 1) Subtract this FS reading from the HI reading to obtain the elevation at point TP-1, i.e.,  $103.02' - 3.68' = 99.34'$ .

Note that the process is repeated in steps e through g below

- e. Move the level instrument to the second level set-up location (X#2) and set up and level the instrument.
- f. Take another rod reading from X#2 back to TP-1. Record this backsight reading (3.34') in the field notebook.
- 1) Add the BS reading to the elevation of TP-1 to give the height of the instrument (HI), i.e.,  $HI = 3.34' + 99.34' = 102.68'$ .
- g. Move the rodman to station TP-2, take a rod reading (4.17'), and record this as a foresight (FS) reading in the field notebook.
- 1) Subtract this FS reading from the HI reading to obtain the elevation at point TP-2, i.e.,  $102.68' - 4.17' = 98.51'$ .

Note that the process is again repeated in steps h through j below.

- h. Move the level instrument to the third level set-up location(X#3) and set up and level the instrument.
- i. Take another rod reading from X#3 back to TP-2. Record this backsight reading (4.00') in the field notebook.

1) Add the BS reading to the elevation of TP-2 to give the height of the instrument (HI), i.e.,  $HI = 4.00' + 98.51' = 102.51'$ .

- j. Move the rodman to station TP-3, take a rod reading (3.95'), and record this as a foresight (FS) reading in the field notebook.

1) Subtract this FS reading from the HI reading to obtain the elevation at point TP-3, i.e.,  $102.51' - 3.95' = 98.56'$ .

Note that the process is again repeated in steps k through m below.

- k. Move the level instrument to the fourth level set-up location (X#4) and set up and level the instrument.
- l. Take another rod reading from X#4 back to TP-3. Record this backsight reading (3.56') in the field notebook.

1) Add the BS reading to the elevation of TP-3 to give the height of the instrument (HI), i.e.,  $HI = 3.56' + 98.56' = 102.12'$ .

- m. Move the rodman to the original BM, take a rod reading (2.11'), and record this as a foresight (FS) reading in the field notebook.

1) Subtract this FS reading from the HI reading to obtain the elevation at point BM, i.e.,  $102.12' - 2.11' = 100.01'$ .

#### FIELD NOTEBOOK FOR SURVEY

STATION	BS	HI	FS	ELEVATION
BM	3.02'	103.02'		100.00'
TP-1	3.34'	102.68'	3.68'	99.34'
TP-2	4.00'	102.51'	4.17'	98.51'
TP-3	3.56'	102.12'	3.95'	98.56'
BM			2.11'	100.01'
SUMS	+13.92'		-13.91'	

BS - FS CHECK =  $+13.92' - 13.91' = +0.01'$

BM CHECK =  $100.01' - 100.00' = +0.01'$

### 3. Checking for Survey Arithmetic Errors

- a. The backsight and foresight columns should be added separately and compared with the difference between the original and final benchmark elevations. The differences should be the same in numerical value and algebraic sign. If either error is present, there is a mistake in the addition or subtraction in the field notebook and the calculations should be refigured.
- b. Difference between the original BM1 elevation and the calculated BM1 elevation after a return check, if they fail to agree, this is known as an error of closure.

### 4. Rules of Differential Leveling

- a. All rod readings are recorded by both surveyors (rodman and level person) as soon as they are checked. All rod readings are recorded in the line that refers to the point sighted.
- b. All arithmetic is carried out as far as is possible with the readings available. The computations are made by each person while the other is moving.
- c. All work must stop until each person agrees on the elevation of each TP.
- d. The backsight and foresight columns should be added separately and compared with the difference between the original and final benchmark elevations. The differences should be the same in numerical value and algebraic sign.
- e. Every benchmark must be used as a turning point.

References:

Ruth, Lawrence O., & Field, Harry L. (1991) Introduction to Agricultural Education, 2ed, New York, Chapman & Hall

Bowers, W., Jones, B. A., Jr., & Olver, E. F. (1973). Engineering Applications in Agriculture. Champaign, IL: Stipes Publishing Company.

Kissam, Phillip. (1978). Surveying Practice (3rd ed.). New York: McGraw-Hill.

Special Materials and Equipment:

Steel tape, chaining pins, range poles, plumb bob, odometer, tripod level, hand level (clinometer). Steel tape, chaining pins. Tripod level, level rod, field notebook.

Name \_\_\_\_\_

Date \_\_\_\_\_

Score \_\_\_\_\_

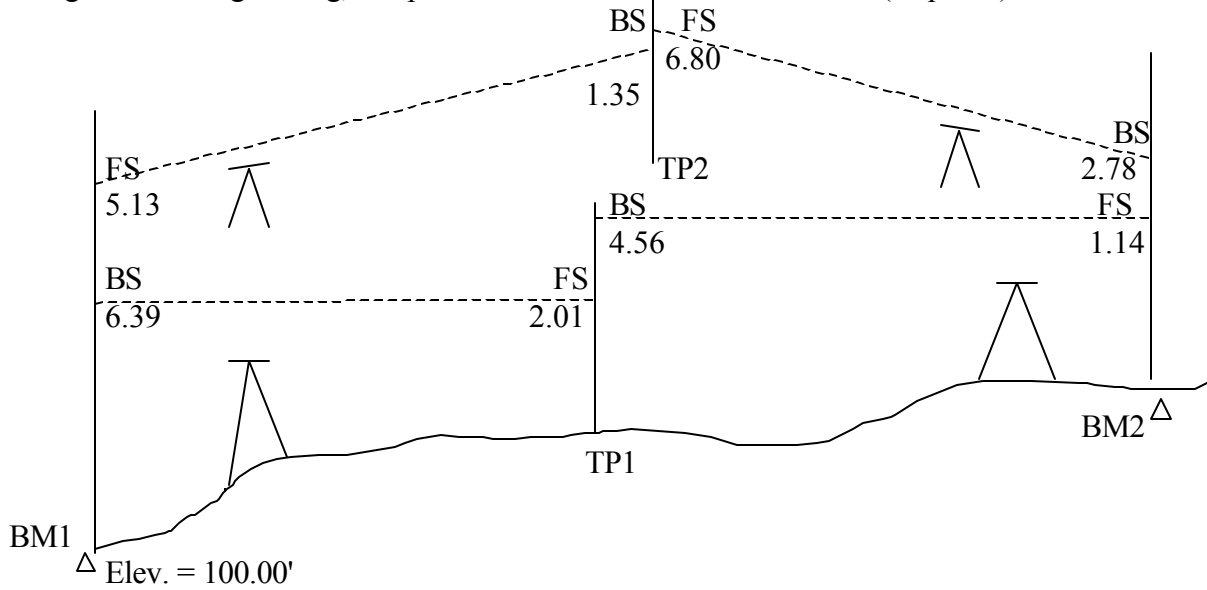
## SURVEYING, UNIT EXAM

Match the terms on the right to the correct definitions on the left by placing the appropriate letters in the blanks provided. (5 points each)

- |  |                              |
|--|------------------------------|
| 1. _____ Elevation of the level line of sight or of the cross hairs in the telescope with respect to the bench mark.                 | A. Bench Mark (BM)           |
| 2. _____ Level line through the instrument, as viewed by the eye; place where vertical hair crosses the horizontal hair.             | B. Foresight (FS)            |
| 3. _____ Method of determining the differences in elevation between two points.  | C. Backsight (BS)            |
| 4. _____ Permanent point of known or assumed elevation from which leveling surveys are started.                                      | D. Height of Instrument (HI) |
| 5. _____ Book used to keep surveying information.  | E. Error of Closure          |
| 6. _____ Rod reading taken on a point of known elevation.  | F. Field notebook            |
| 7. _____ Rod used in leveling, normally graduated in tenths and hundredths of a foot.  | G. Differential Leveling     |
| 8. _____ Method of determining the elevation of a series of points at measured intervals along a line.                               | H. Profile Leveling          |
| 9. _____ Rod reading taken on a point of unknown elevation.  | I. Level Rod                 |
| 10. _____ Difference between the original BM1 elevation and the calculated BM1 elevation after a return check, if they fail to agree | J. Line of Sight             |



Using the following reading, complete the field notes on the form below. (50 points)



STA	BS	HI	FS	ELEV
BM1				
TP1				
BM2				
TP2				
BM1				

Error = \_\_\_\_\_ - \_\_\_\_\_ = \_\_\_\_\_

## Answer Sheet

## Worksheet # 1

- A. NE 1/4, Sec17, T6N, R5E, BM
- B. SW 1/2, NW 1/4, Sec17, T6N, R5E, BM
- C. E 1/2, NW 1/4, Sec17, T6N, R5E, BM
- D. NE 1/4, SW 1/2, Sec17, T6N, R5E, BM
- E. NW 1/4, SW 1/4, SW 1/4, Sec17, T6N, R5E, BM

## Worksheet #3

- 1. 6.17
- 2. 6.15
- 3. 6.14
- 4. 6.09
- 5. 6.06
- 6. 6.05
- 7. 5.97
- 8. 5.89
- 9. 5.85
- 10. 5.84

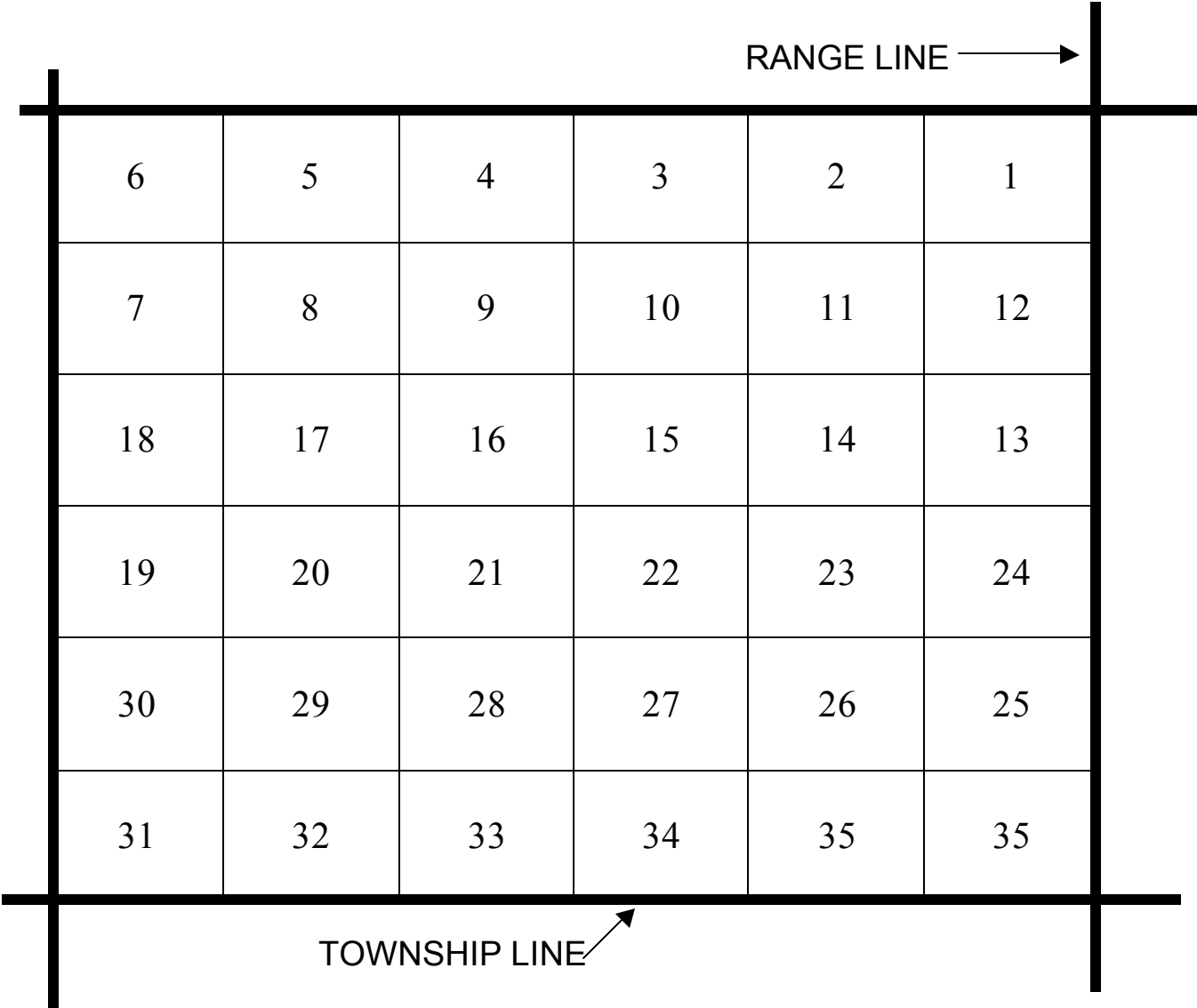
## Unit Exam

- 1. D
- 2. J
- 3. G
- 4. A
- 5. F
- 6. C
- 7. I
- 8. H
- 9. B
- 10. E

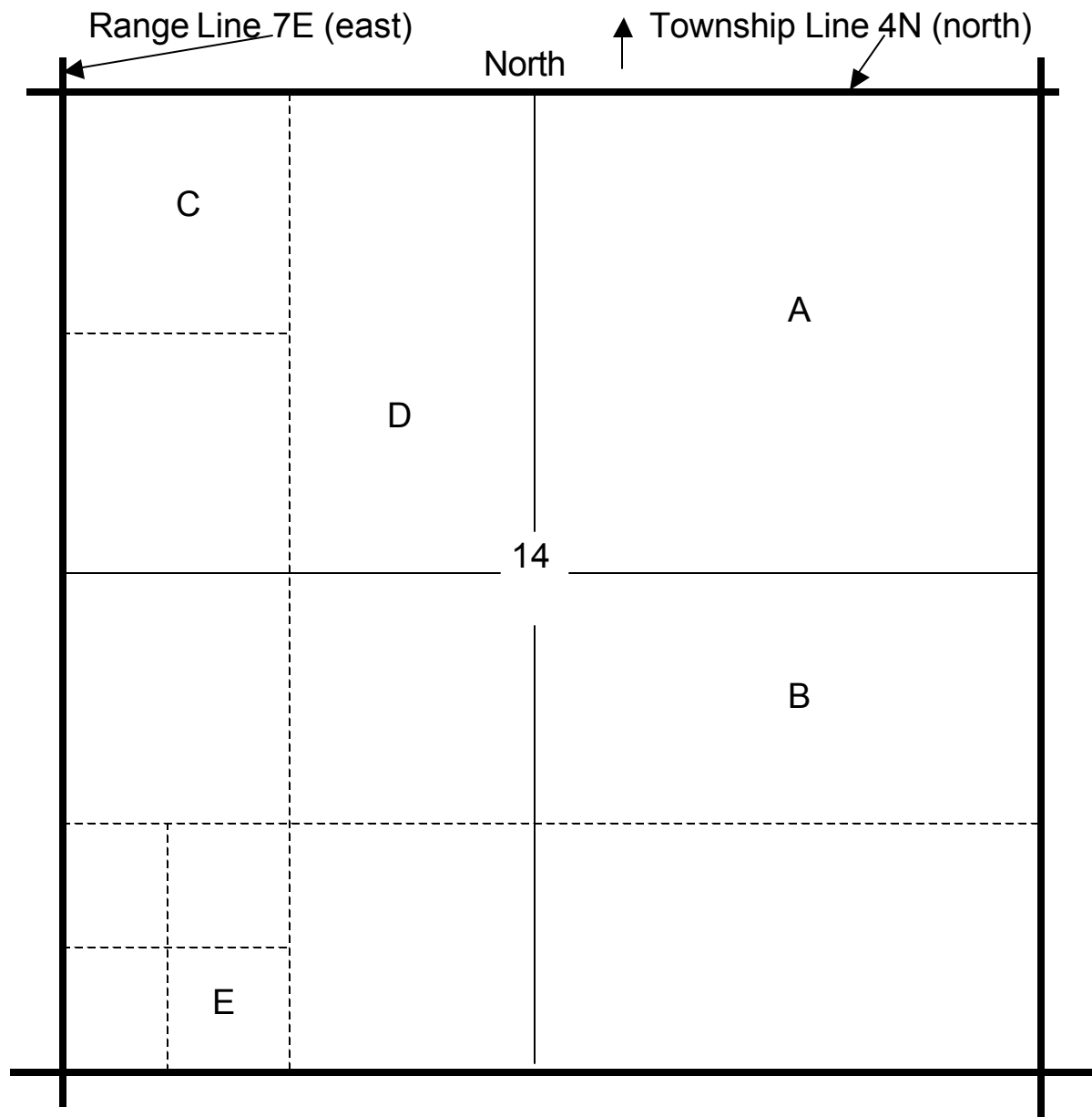
STA	BS	HI	FS	ELEV
BM1	6.39			100.00
		106.39		
TP1	4.56		2.01	104.38
		108.94		
BM2	2.78		1.14	107.80
		110.58		
TP2	1.35		6.80	103.78
		105.13		
BM1			5.13	100.00

$$\text{Error} = \underline{100.00} - \underline{100.00} = \underline{0.00}$$

SUBDIVISION OF A TOWNSHIP



## SUBDIVISION OF A SECTION



A = NE 1/4, S14, T4N, R7E, BM (BOISE MERIDIAN)

B = N 1/2, SE 1/4, S14, T4N, R7E, BM

C = NW 1/4, NW 1/4, S14, T4N, R7E, BM

D = E 1/2, NW 1/4, S14, T4N, R7E, BM

E = SE 1/4, SW 1/4, SW 1/4, S14, T4N, R7E, BM

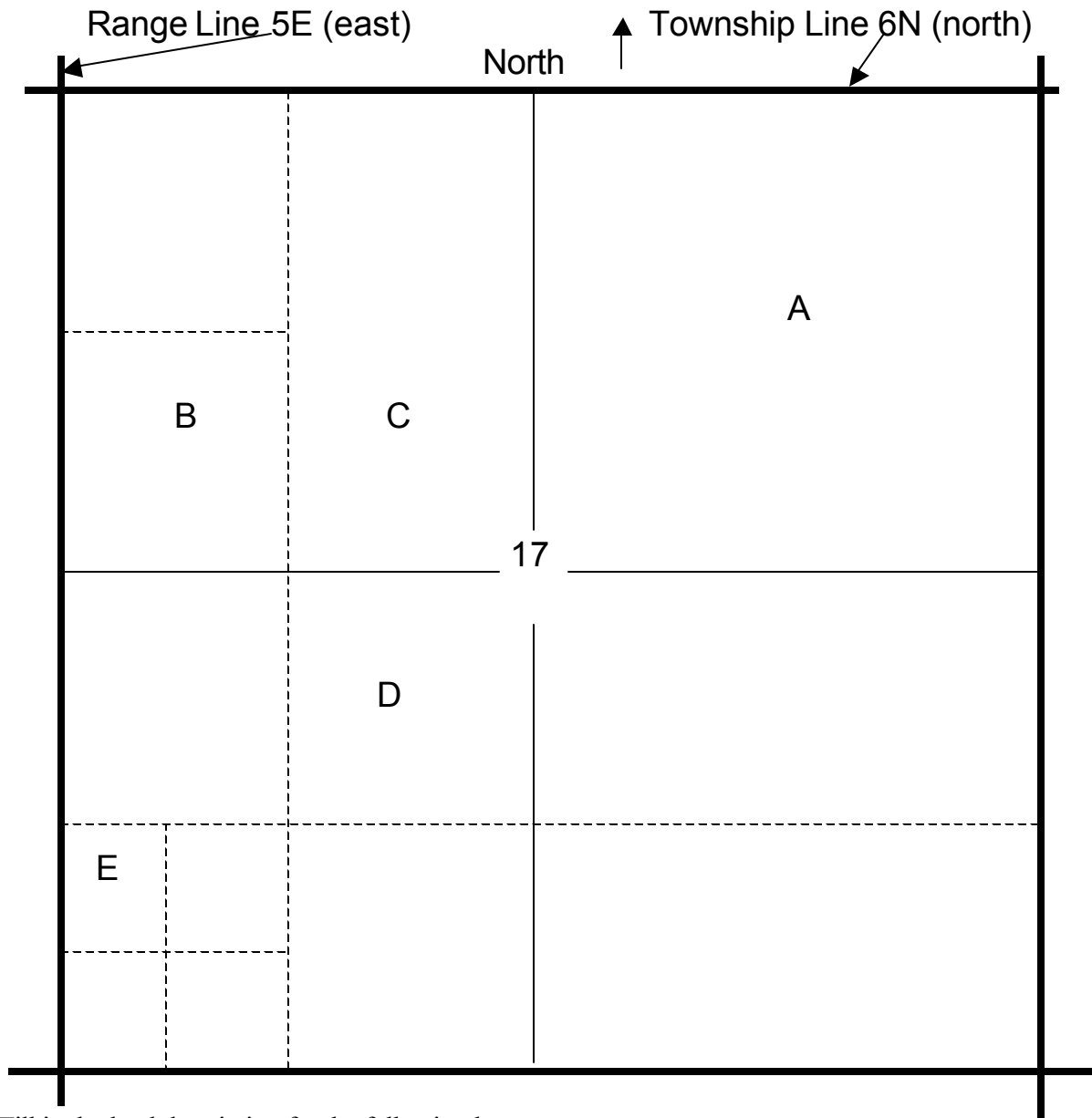
130U-29  
Worksheet #1

Name \_\_\_\_\_

Date \_\_\_\_\_

Score \_\_\_\_\_

SUBDIVISION OF A SECTION



Fill in the land description for the following letters.

A =

B =

C =

D =

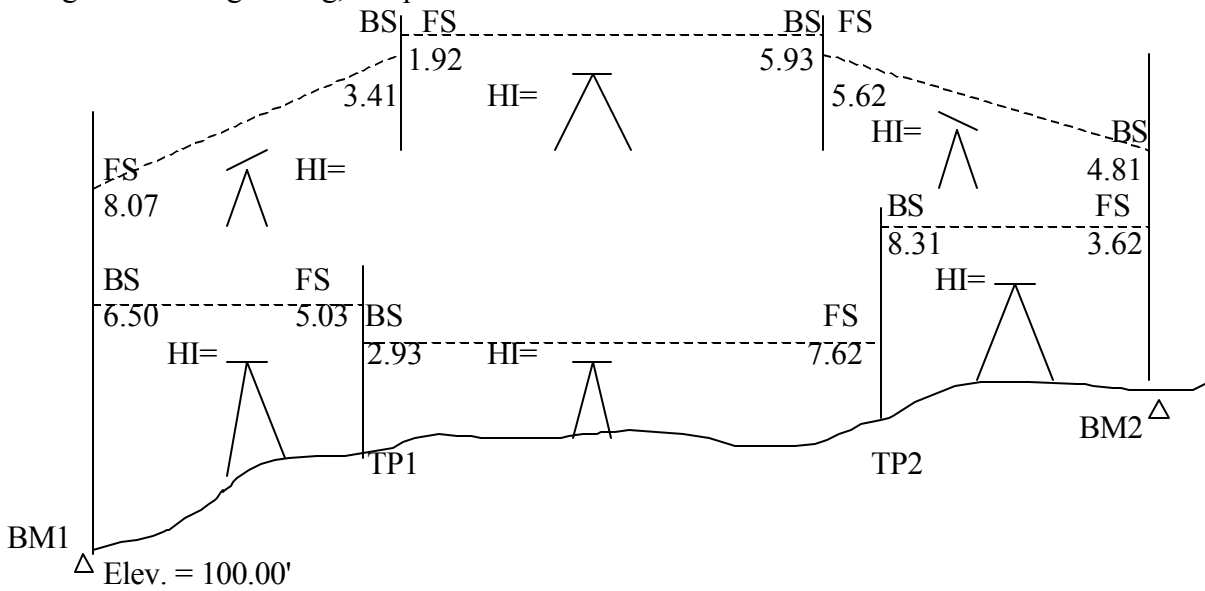
E =

130U-30  
Worksheet #2

Name \_\_\_\_\_  
Date \_\_\_\_\_  
Score \_\_\_\_\_

DIFFERENTIAL LEVELING PROBLEM

Using the following reading, complete the field notes on the form below.



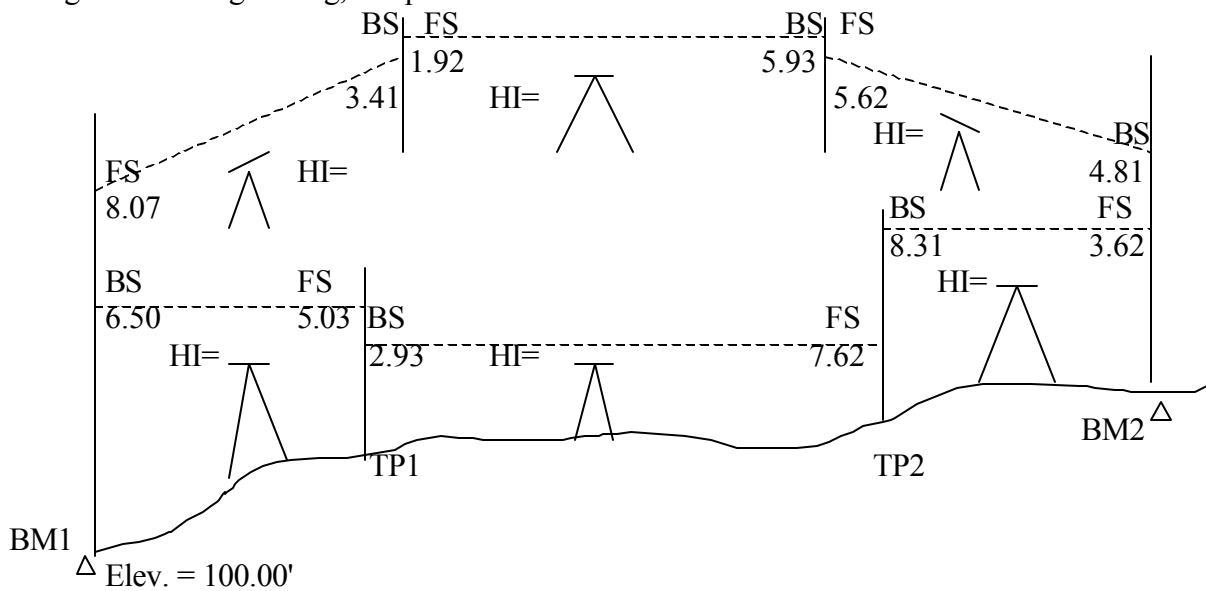
STA	BS	HI	FS	ELEV
BM1				
TP1				
TP2				
BM2				
TP3				
TP4				
BM1				

BM1 – 2ed BM1 = error

\_\_\_\_\_ - \_\_\_\_\_ = \_\_\_\_\_

## DIFFERENTIAL LEVELING PROBLEM

Using the following reading, complete the field notes on the form below.

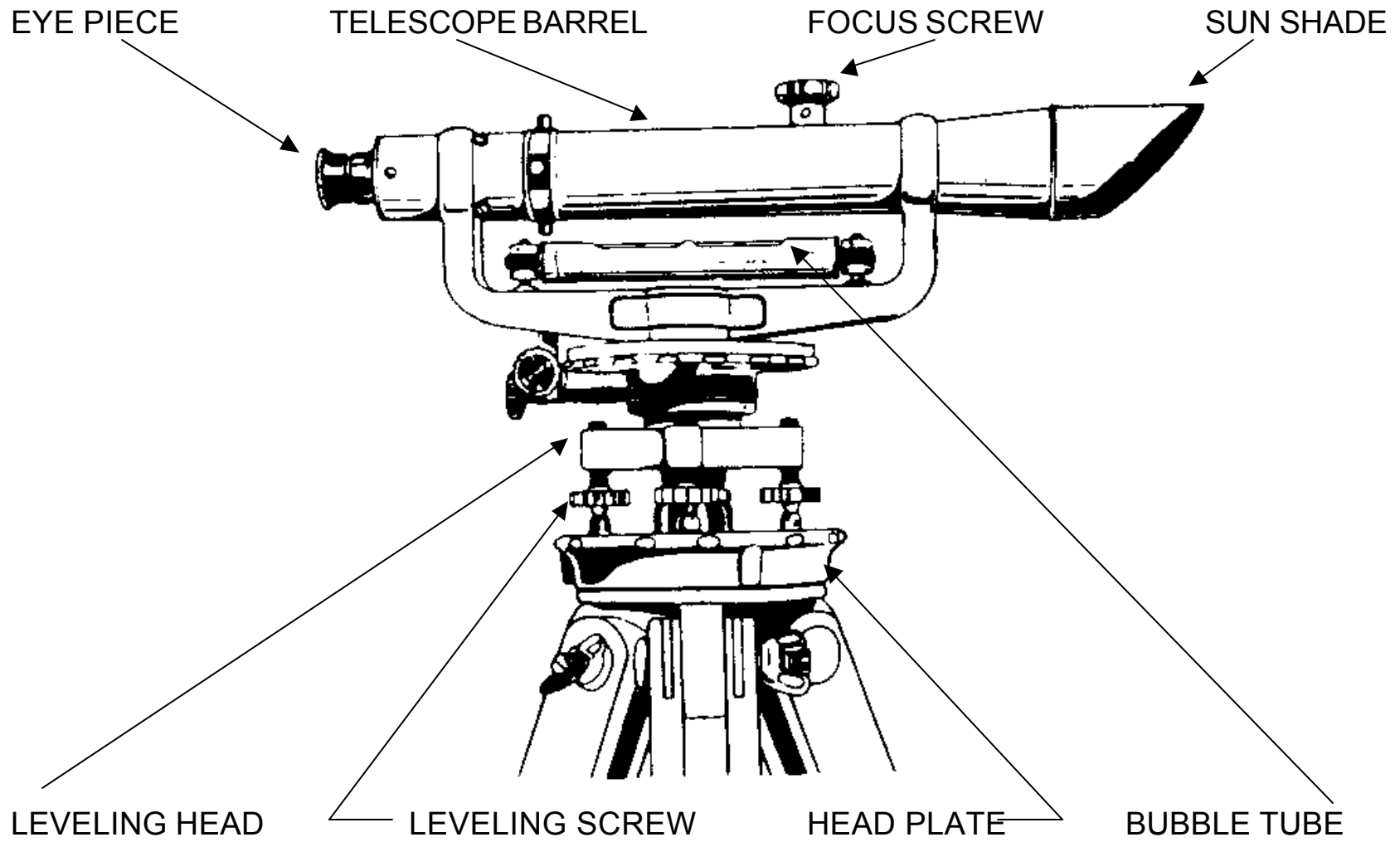


STA	BS	HI	FS	ELEV
BM1	6.50			100.00
		106.5		
TP1	2.93		5.03	101.47
		104.40		
TP2	8.31		7.62	96.78
		105.09		
BM2	4.81		3.62	101.47
		106.28		
TP3	5.93		5.62	101.66
		106.59		
TP4	3.41		1.92	104.67
		108.08		
BM1			8.07	100.01

$$(BM1) 100.00 - (BM2) 100.01 = 0.01 \text{ Error}$$

130U-32

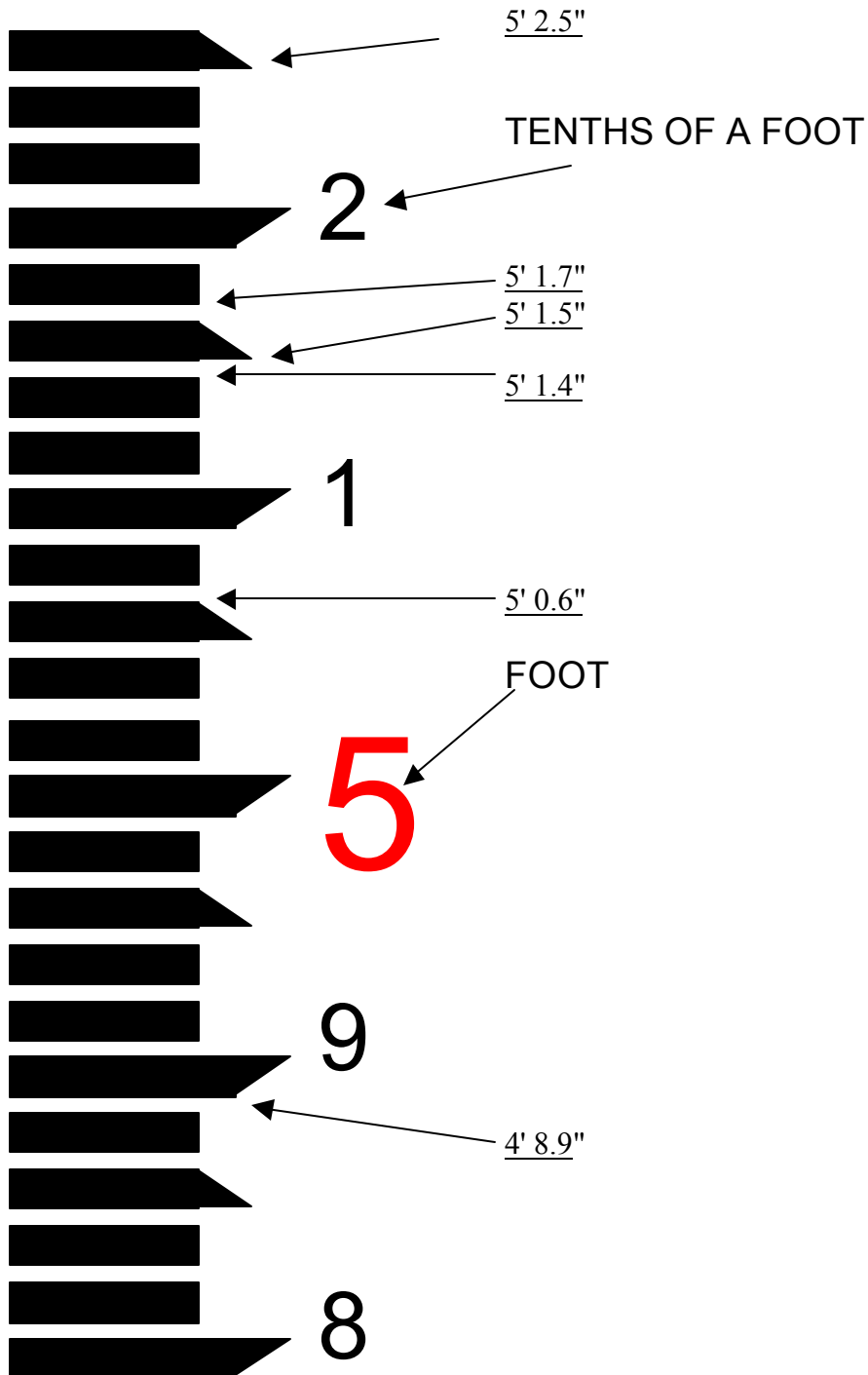
# PARTS OF THE LEVEL





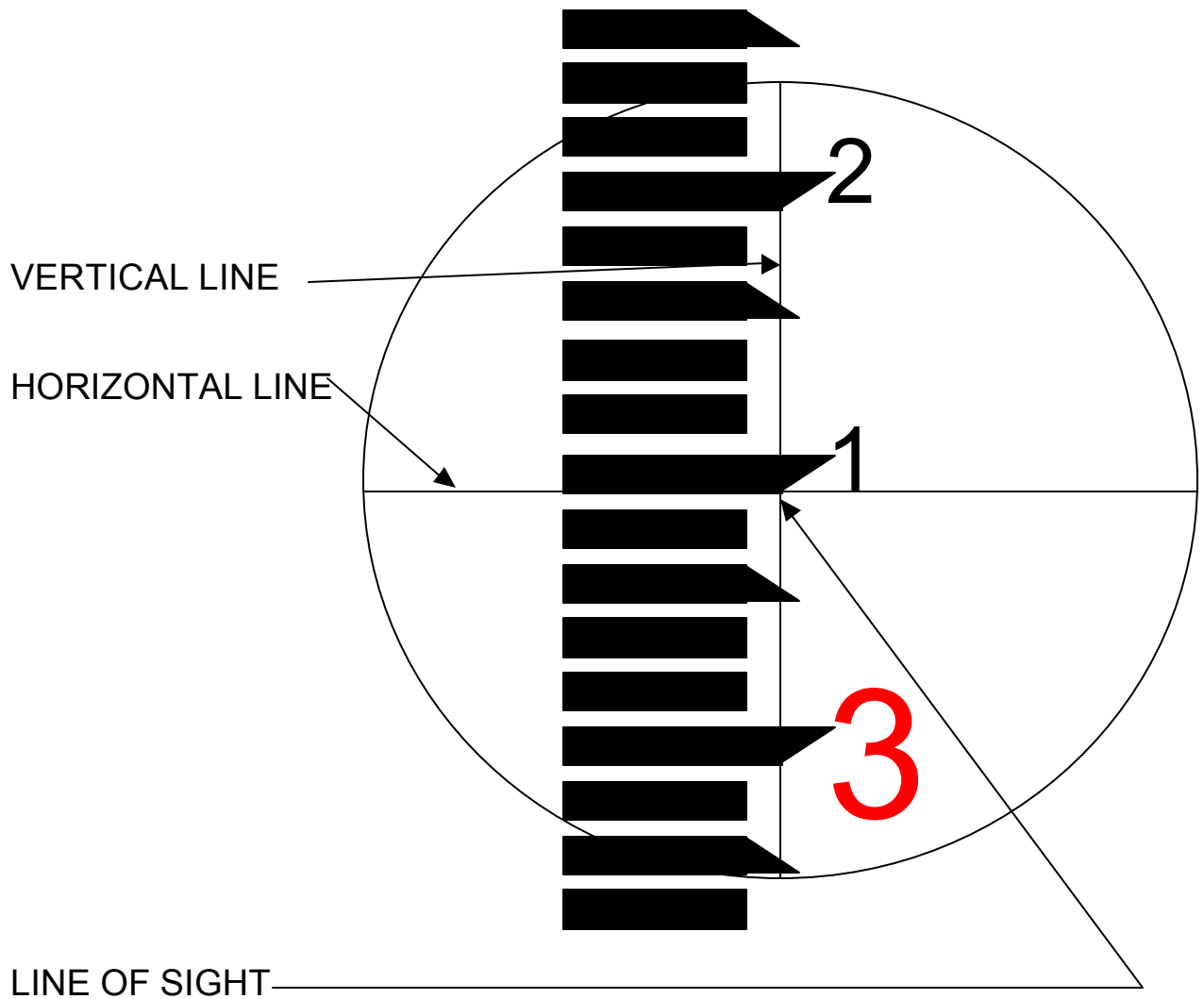
## READING THE LEVELING ROD

Each corner and each point, is a point of measurement. There are 10 points of measurements between numbers.



## CROSS HAIRS IN THE TELESCOPE

### TAKING THE READING



Take the reading at the line of sight.  
The reading on this level rod is 3.09 feet

Name \_\_\_\_\_  
Date \_\_\_\_\_  
Score \_\_\_\_\_

Worksheet #3, Reading the Level Rod

Fill in the measurement reading in the blanks, answer questions to the nearest hundredths.

